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It thus appears that for large star discs the increase of diameter does not increase quite so rapidly as the cube root of the duration, and tends towards the fourth root. For faint stars, on the other hand (as in the third set of plate 18), the rapidity surpasses the cube root, and tends to the square root. This suggests how both Bond's and Pritchard's results may be true under different circumstances.

Photographic Analyses of the Great Nebula M 42 *and* 43 *and* *h* 1180 *in Orion.* By Isaac Roberts.

By the term photographic analyses is to be understood the appearances which this nebula presents with exposures of the negatives varying between 5 seconds of time and 205 minutes, and when the details are studied by aid of the gradations of the nebulosity which have been obtained in this manner we are enabled to compare the relative actinic power of the light in different parts of the nebula.

We are not to infer that any given exposure of a plate for, say, 15 minutes, or for any other number of minutes, represents a constant quantity of photographic effect which is always available for accurate comparison with other exposures during corresponding intervals of time, for it is found that the photographic effect generally varies from moment to moment during any exposure of a plate owing to atmospheric absorption or extinction of the light; but by taking a number of photographs and selecting them so as to exhibit small gradations in the density of the nebulosity, we see more of the structure than we probably can by any other method, and this applies with greater force to enlargements than to the original negatives.

In the illustrations now presented,[*] gradations are shown on seven enlarged photographic plates with eleven exposures of the negatives. The enlargements are to five times the size of the negatives.

PLATE I.

The negative of which this plate is an enlargement was taken on February 16, 1889, and has upon it five consecutive exposures of 5 seconds, 30 seconds, 1 minute, 3 minutes, and 6 minutes respectively, and they show such of the stars and so much of the nebulosity as on that occasion were imprinted on the film. The four stars which form the trapezium are shown on the first exposure of 5 seconds, and they increase in diameter and in density till in the fifth exposure of 6 minutes they form one image with an irregular outline. The nebulosity begins to appear round θ in the third exposure of 1 minute, and in the 6 minutes' exposure it is well developed and characteristic. It will

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[*] The photographs are placed in the Library.

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be observed when the photographs are compared with the drawings of this nebula by Lord Rosse that there are many points of resemblance between them in the outlines as well as in the distribution of the nebulosity, and it is apparent that great care and skill have been exercised in the observing and in the drawing of the details which occupied, as Lord Rosse informs us, "every available hour during the winter months of seven seasons." When the photographic plates are exposed for 15 minutes and upwards these resemblances more or less disappear in the cumulative density of the nebulosity.

PLATES 2, 3, and 4.

These three plates were enlarged from negatives taken one on each of the following dates: February 16, 1889, December 18, 1886, and February 20, 1889, with 15 minutes' exposures, and they illustrate the differences in the density of the nebulosity due chiefly to atmospheric causes at the time of exposure.

On comparing these photographs with the well-known photograph taken by Mr. Common, on January 30, 1883, I have not detected by eye observations that any changes in the structure of the nebula have taken place during the interval of six years that has elapsed between them, but the examination should be more carefully made by measurements before full reliance is placed on this statement. It is obvious, if we compare the positions of the stars within the nebula as they are shown on the charts by Lord Rosse and by Bond, that changes in the relative positions of some of them have taken place since the year 1866, and I shall here just refer to one as an illustration. In the trapezium the two stars numbered 65 and 69 on Lord Rosse's chart are shown much closer to each other than the stars numbered 67 and 73, and Bond's chart agrees with Lord Rosse's, whereas in the photographs these pairs are nearly equidistant.

PLATES 5 and 6.

The negative of plate 5 was taken on February 18, 1889, with an exposure of 30 minutes, and that of plate 6 on December 24, 1888, with an exposure of 81 minutes. Both photographs show great extensions of the nebula, and M 43 is joined to M 42; *h* 1180 is also well developed with its characteristic dark cross streams.

PLATE 7.

The negative was taken on February 4, 1889, with an exposure of 205 minutes, and supplies us with evidence that M 42 and 43 and *h* 1180 form one gigantic nebula. The links joining *h* 1180 with the other portions are shown also on another negative which I took with two exposures upon it, one on January 22, 1889, and the other on February 3. The exposures were of

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2 hours and 2½ hours respectively. The evidence and confirmation place it beyond reasonable doubt that the links shown are realities, and though they supply us with vastly extended knowledge of the dimensions, and form, and details of this nebula, yet leave us with unsatisfied desire to see more, and probably to find that the nebula will be shown to have a symmetrical form in external outline, but is in a state of strong internal commotion. Next year we ought to be able to supply the missing links and see it as a finished picture. In the meantime we ought, with all gratitude, to admire the patient, long-suffering endurance of those martyrs to science, who during the freezing nights of many successive winters plotted, with pencil in benumbed fingers, the crude outlines which have been handed down to us as correct drawings of this wonderful nebula, which we can now depict during four hours of clear sky with far greater accuracy than is possible by the best hand-work in a lifetime.

Note on an Apparatus for correcting the Driving of the Motor Clocks of large Equatorials for long Photographic Exposures.

By A. A. Common, F.R.S.

In giving long exposures in astronomical photography it is absolutely essential that some means be adopted to prevent any shift of the image on the photographic plate during exposure; for if irregularities in clock-driving, changes due to flexure of instrument, and alterations in apparent position due to refraction are not immediately corrected the photograph will be blurred and the fine detail lost. These irregularities are further complicated in the case of reflectors by changes due to alterations of temperature, and by variations of strains in the mirror as the telescope moves round.

There are obviously two methods by which the image of the object to be photographed can be kept in exactly the same position on the plate during exposure: either the telescope itself must be moved by means of its fine screws for slow motion in right ascension and declination, or the photographic plate must be moved during the exposure. The first method has been adopted by the Paris Conference for the instruments to be used in charting the stars. A finder of 9 inches' aperture is to be attached to each photographic instrument, the optic axes to be parallel; and the stars are to be watched throughout the exposure and any shift immediately checked by the slow-motion screws of the instrument. For small instruments this method is perhaps capable of meeting all the difficulties, for the slow motions can be made to work smoothly; but it is impossible to apply it properly to large and heavy instruments, especially to large reflectors where the parallelism of the finder and the axis of the mirror can never be rigidly maintained.